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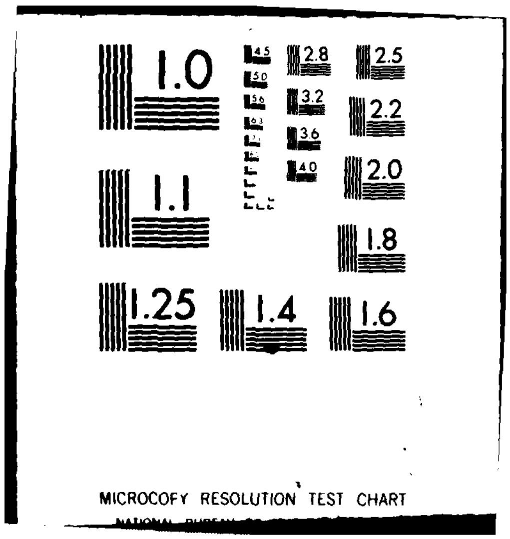
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# EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER (HTW), CHILLED WATER (CHW), FUEL GAS, AND COMPRESSED AIR

## DESIGN MANUAL 3.8



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**20. ABSTRACT (Continue on reverse side if necessary and identify by block number):**

Basic design guidance developed from extensive reevaluation of facilities is presented for use by experienced architects and engineers. Criteria are given for the design of an exterior distribution piping system for supplying utility steam, high temperature water (HTW), chilled water (CHW), cooling or condensing water, fuel gas, and compressed air to various buildings and facilities and for returning condensate and water to the central plant.

(continued on reverse)

20. Data required for the design include information on loads and fluid conditions, fluid characteristics, and distribution site locations. Factors governing tests for field permeability, soil resistivity, soil stability, and water conditions are given as is information on distribution pipe sizing, valves and supports, distribution methods, and piping specifications and codes. Contents also cover owning, operating, and maintenance costs of permanent or temporary sites.

## ABSTRACT

Basic design guidance developed from extensive reevaluation of facilities is presented for use by experienced architects and engineers. Criteria are given for the design of an exterior distribution piping system for supplying utility steam, high temperature water (HTW), chilled water (CHW), cooling or condensing water, fuel gas, and compressed air to various buildings and facilities and for returning condensate and water to the central plant. Data required for the design include information on loads and fluid conditions, fluid characteristics, and distribution site locations. Factors governing tests for field permeability, soil resistivity, soil stability, and water conditions are given as is information on distribution pipe sizing, valves and supports, distribution methods, and piping specifications and codes. Contents also cover owning, operating, and maintenance costs of permanent or temporary sites.

## FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This manual uses, to the maximum extent feasible, national, industrial, technical professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters (Code 04). As the design manuals are revised, they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with SECNAVINST 5600.16.

W. M. Zobel
Rear Admiral, CEC, U. S. Navy
Commander
Naval Facilities Engineering Command

MECHANICAL ENGINEERING DESIGN MANUALS

| DM Number | Chapter superseded in Basic DM | Title |
|---|---|---|
| 3.1 | 1 | Plumbing Systems |
| 3.2 | 2,2A | Industrial and Municipal Type Incinerators |
| 3.3 | 3,4,5 | Heating Ventilation and Air Conditioning Systems |
| 3.4 | 6 | Refrigeration Systems for Cold Storage |
| 3.5 | 7,10 | Compressed and Vacuum Air Systems |
| 3.6 | 8 | Central Heating Plants |
| 3.7 | 9 | Power Plants |
| 3.8 | 11 | Exterior Distribution of Utility Steam HTW, CHW, Fuel Gas and Compressed Air |
| 3.9 | 13,14 | Elevators, Escalators, Dumbwaiters and Pneumatic Tube Systems |
| 3.10 | 15 | Noise and Vibration Control of Mechanical Equipment (Army TM-5-805-4) |
| 3.11 | 16 | Solid Waste Handling |
| 3.12 | -- | Central Building Automation Systems (Army preparing this manual) |
| 3.14 | -- | Power Plant Acoustics (Army TM-5-805-9) |
| 3.15 | -- | Air Pollution Control (Tri-Service Manual TM-5-815-1/AFR 19-6) |
| 3.16 | -- | Thermal Storage |
| 3.17 | -- | Cogeneration of Steam and Electricity |
| 3.18 | -- | Domestic Water Requirements for Medical and Dental Facilities |

Chapter 12, Liquified Petroleum Gases, will be included in DM-22.

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EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER (HTW), CHILLED WATER (CHW), FUEL GAS AND COMPRESSED AIR

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TABLES

# EXTERIOR DISTRIBUTION OF UTILITY STEAM, HIGH TEMPERATURE WATER (HTW), CHILLED WATER (CHW), FUEL GAS, AND COMPRESSED AIR

## Section 1. INTRODUCTION

1. SCOPE. Data and criteria in this design manual apply to the exterior design of distribution piping for supplying certain services from central generating plants to various buildings and facilities and for returning such spent services to the plants.

2. CANCELLATION. This design manual on the exterior distribution of utility steam, high temperature water (HTW), chilled water (CHW), fuel gas, and compressed air, NAVFAC DM-3.8, cancels and supersedes Chapter 11 of DM-3, Mechanical Engineering, of September 1972.

3. RELATED CRITERIA. Criteria for certain items related to the subject matter of this design manual are covered elsewhere and in other DM-3 series of design manuals.

## Section 2. FLUIDS AND UTILITY DISPERSION

1. TYPES OF EXTERIOR DISTRIBUTION SYSTEMS. Types of exterior distribution systems should be as follows:

a. Steam. System supplies heat in the form of steam from a central steam generating plant to several buildings or building groups for space heating (such as unit heaters, radiators, convectors, heating coils, or other heating devices) and process work (such as domestic hot water heaters, laundry machinery, cleaning and plating tanks, kitchen equipment, or other devices using steam), returning the condensate, where possible, to the central plant (see DM-3 series).

b. High Temperature Water (HTW). System circulates high temperature water which supplies heat from a central heating plant to several buildings for space heating and process work, and returning the water to the central plant (see DM-3 series).

c. Compressed Air. System supplies compressed air from a compressor plant to docks, wharves, piers, shop, hangars, and other structures (see DM-3 series).

d. Chilled Water (CHW). System circulates chilled water from a central refrigeration plant to several buildings for space air conditioning (see DM-3 series), returning the water to the central plant.

e. Cooling or Condensing Water. System distributes cooling water from a central source (such as a bay, stream, or cooling tower) to several buildings for condensing steam or refrigerants or for cooling water jackets or stuffing boxes. The water is then returned to the source (cooling tower) or sent to waste in once-through systems (see DM-3 series).

f. Fuel Gas distribution. System distributes fuel gas to several buildings for fuel gas burning operations.

2. INFORMATION REQUIRED FOR DESIGN. Information required for design will be as follows:

a. Loads and Fluid Conditions. For approximate conditions, see Table 1.

(1). See NAVFAC P-272, Part 1, for steam requirements for hospitals, laundries, shops, various facilities, and equipment therein.

(2) The actual loads and conditions should be determined from the design of each building and/or facility.

b. Total Distribution Load. For demand factors, see Table 1.

3. FLUID CHARACTERISTICS. For criteria on fluid characteristics, use sources below or those in Section 2.

a. Steam. Use criteria in Thermodynamic Properties of Steam (Keenan and Keyes).

b. Condensate. For the economics of returning condensate, use the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Handbook and Product Directory.

c. High Temperature Water. Use ASHRAE Handbook and Product Directory.

d. Compressed Air. For data on fluid characteristics of compressed air, see DM-3 series.

e. Fuel Gas. USE ANSI B31.2 Fuel Gas Piping.

4. DISTRIBUTION SITE LOCATIONS. Fluid distribution site locations should be according to the following:

a. Location Factors for Each System. For location factors for each system, see Table 2.

b. Subsurface Explorations. When underground systems are specified, a thorough investigation should be made of ground and water conditions.

(1) This survey should be made at a time of year when the highest water table is expected to exist. Exploration methods indicated in Soil Mechanics, Foundations, and Earth Structures, NAVFAC DM-7 series, should be followed.

(2) Explorations (borings or test pits) should be made at least every 100 feet along the line of a proposed system. If changes of stratifications are noted, the boring spacings should be decreased so an accurate horizontal soil profile may be obtained.

(3) All explorations should be extended 5 feet below the expected elevation of a system to determine ground water conditions (see NAVFAC Guide Specification TS-15705).

## TABLE 1
## Distribution Loads and Fluid Conditions

| Fluid | Use | Capacity[1] | Fluid conditions psig, in-Hg, degrees F | Demand factors[2] | Comments |
|---|---|---|---|---|---|
| Steam...... | Auxiliary power....... | Determined by heat balance.......... | Boiler steam. | 1.0 ........... | Feedwater and fuel oil heating.... |
| | Heating and snow melting. | See criteria in DM-3.3 ........... | 2 to 10 ..... | 1.0[3] for heating radiation 0.8[3] for ventilation. | ............ |
| | Process...... | Laundry .......... | 100 ........ | 0.65 .......... | 7 hr/day, 5 days/week, normally. |
| | | Kitchen .......... | 10 to 40 ... | 1.0 ........... | 2-8 hr/day, 7 days/week, normally. |
| | | Bakery ........... | 10 ......... | 1.0 ........... | 8 hr/day, 5 days/week, normally. |
| | | Dry cleaning ..... | 70 ......... | 0.65 .......... | ............ |
| | | Hospital ......... | 40 to 60 ... | 0.65 .......... | ............ |
| | | Laundry HW ....... | 5 to 45 .... | 0.65 .......... | 7 hr/day, 5 days/week, normally. |
| | | Dom HW: DM-3.1 .. | 5 to 45 .... | 0.65 .......... | ............ |
| | Refrigeration. | Tons x steam rate/t | Boiler steam pres. 26-28 in. Hg. vac. | 1.0 ........... | Turbine driven centrif. compressor. |
| | | Tons x steam rate/t | 12 ......... | 1.0 ........... | Absorption machine. |
| Condensate return.... | Distribution loss........ | | | | |
| | Boiler feed.. | Losses CBD or BO: Determined by amount and analysis of makeup. Process-Depends on usage. Distribution 10 percent. | 20 to 60 ... | 1.0 for continuous operation of condensate pumps. 1.5 to 3 for intermittent operation of condensate pumps. | Check economics of returning condensate. |
| HTW (Supply and return) | Heating and snow melting. | Same criteria as for steam............. | 10 to 100 .. | ................. | ............ |
| | Process....... | ................... | Same as for steam. | Same as for steam. | ............ |
| Chilled water supply and return. | Refrigeration. | gpm = $\frac{12{,}000 \text{ Btu/t} \times \text{tons}}{500 \times (t_s - t_r)}$ | Supply: 42° F. to 45° F. Return: 52° F to 60° F. Pressure depends on friction and static heads. | 1.0[3]......... | ............ |
| Condenser water..... | Refrigeration. | 3 gpm/t | Supply 85° F. Return 105° F. | 1.0 ............ | ............ |
| | Power......... | gpm = $\frac{\text{steam pph} \times 950 \text{ Btu/lb}}{500 \times (t_s - t_r)}$ | Pressure depends on friction and static heads. | 1.0 ............ | See NAVFAC DM-3 series |
| Fuel Gas... | Process fuel gas burners. | ................... | .............. | ................ | See NAVFAC DM-3 series |
| | LPG gas burners. | ................... | .............. | ................ | See NAVFAC DM-3 series |
| Compressed air | Low pressure mdm. pressure high pressure | ................... | .............. | ................ | See NAVFAC DM-3 series |

[1] $t_s$ = Water supply temperature; $t_r$ = water return temperature.
[2] Demand factors should be applied to total connected loads.
[3] Values shown are approximate. Actual Demand Factor is a site-specific determination and should be based on actual load diversification.

TABLE 2
Location Factors for Each Distribution System

| Item | Determine the following |
|---|---|
| Load centers.......... | Maximum demand load of system. (See criteria in Table 11 and ascertain requirements of all facilities.) |
| | Distance from generating plant. |
| | Basements or crawl spaces under buildings available for piping. |
| | Location of entry of system to load center structure. |
| | Location or need of meters for billing purposes. |
| | Future expansion. |
| Route................. | Existing tunnels or trenches available for system. |
| | Above ground obstructions, such as rivers, roads, railroads, structures, etc. |
| | Below ground obstructions, such as tunnels, trenches, piping, rock, etc. |
| | Location of expansion loops or joints. |
| | Master Plan. (See DM-1 and P-340 for criteria.) |
| Site.................. | For above and underground systems: |
| | Ground contours along route. |
| | For underground systems: |
| | Borings every 100 ft along route (See Par 4b.) |
| | Absorption test (See Par 4c.) |
| | Resistivity test (See Par 4d.) |
| | Stability of soil (See Par 4e.) |
| | Water table survey made at time of highest levels. |
| | Maximum, normal, and minimum ground water levels. |
| | Frost level. |
| | Location of distribution line drainage. |
| Coordination.......... | Installation of other related distribution systems and manholes. |
| | Interference with electric distribution lines and manholes. |
| | Interference with water supply and fire extinguishing systems. |
| | Interference with sanitary and storm sewers and manholes. |
| | Interference with ground drainage lines, catch basins, and manholes. |
| | Interference with fuel distribution systems. |
| | Excavation and backfill. |
| | Landscaping. |
| Cooperation........... | Local rules and regulations (permits, tests, approvals, etc.). |
| Hazards............... | See DM-1 for criteria. |
| Unit costs............ | Excavation of soil and rock and of backfill. |
| | Piping material. |
| | Piping insulation or covering. |
| | Pipe conduit. |
| | Construction of manholes. |
| Local labor........... | Availability and costs. |
| Local material........ | Availability and costs. |

(4) Particular attention should be given to the following factors:

(a) The possibility of surface runoff seeping into a backfilled trench and percolating down toward a system at a rate greater than the ability of the ground below the system to carry off the water.

(b) Areas where ponding may occur, either along a sloping surface or in low flat areas.

(c) In order to determine the permeability of the ground below a system, see below.

(5) Field Permeability Test. Field permeability tests should be as follows:

(a) Generally, field permeability tests should be made along the line of a trench at intervals of approximately 100 feet as follows:

(i) Holes should be dug approximately 1 foot square to a depth of 2 feet below the approximate bottom of a trench.

(ii) Each hole should be filled with water to the bottom elevation of a trench.

(iii) After the water has completely seeped away, each hole should be immediately refilled with water to the same depth.

(iv) If it requires 20 minutes or less for the water to drop 2 inches, the soil shall be considered dry; otherwise, consider it as saturated at times.

(b) Use test results as follows:

(i) If the soil is saturated at times, no further tests are required. Class A underground conduit systems for wet soils should be used.

(ii) If the soil is dry as defined above, permeability test holes should be deepened an additional 3 feet to determine if the water table is within 5 feet of the trench bottom (see NAVFAC Guide Specification TS-15705 for site classification criteria).

(6) Soil Resistivity. Soil resistivity should be handled as follows:

(a) If metal casing conduits are considered, soil resistivity readings should be taken along a conduit line.

(b) A cathodic protection system shall be installed to protect metal conduits and manholes at all sites where soil resistivity is less than 30,000 per centimeter cube (ohm-cm) or where stray direct currents can be detected underground.

(7) Soil Stability. During the above survey the soil stability should be observed and noted. Use NAVFAC DM-7 series for criteria.

5. ECONOMIC STUDIES. Economic studies must include owning, operating, and maintenance costs. Whether or not the site is permanent or temporary also should be a consideration. First consideration should be given to an above ground system, which in most cases, will be economically advantageous to the Government.

a. Annual Owning, Operating, and Maintenance Costs. Owning and operating maintenance costs will be as follows:

(1) Within limitations, the lowest overall sum of these costs should be the basis for selecting a type of distribution system and a route (esthetics notwithstanding).

(2) Annual owning costs should be based on 25-year retirement of installation costs at 10 percent compound interest rate.

(3) Operation and maintenance costs depend on the type of system design and past experience with various systems.

b. Aboveground and Underground Systems. Permanent versus temporary use, high water table, and degree of hazard should be considered in selecting a system.

c. Type of Underground System. Suitability of types of approved systems should be considered.

d. Condensate Return Costs. For criteria on condensate return costs, see DM-3 series.

e. Steam Versus High Temperature Water Distribution. For criteria on steam versus high temperature water distribution, see DM-3 series.

f. High Pressure (above 50 psig) Steam Versus Low Pressure (0 to 15 psig) Steam Distribution. Compare costs of higher pressure pipe, valve, and fitting standards against lower pressure standards plus costs of pressure reducing stations in selecting the most economical system. Medium pressure steam systems (15 to 50 psig), if operationally adequate and economically justifiable, also may be used.

## Section 3. DISTRIBUTION PIPING DESIGN

1. SIZING. Sizing of distribution piping will be as follows:

a. Equivalent Lengths of Piping. To the straight lengths of pipe along a pipeline route, add equivalent lengths for valves and fittings as indicated in Table 3.

b. Steam Piping. Design considerations for steam piping will be as follows:

(1) Steam Flow Charts. For charts for pressures of 30, 50, 100, and 150 pounds per square inch gage (psig), see Figure 1a, Figure 1b, Figure 2a, and Figure 2b. These charts show weight-flow rate pressure drop and velocities of saturated steam in Schedule 40 steel pipe. By selecting all pipe sizes on an optimum pressure drop, the total pressure drop of a pipeline may be estimated from an equivalent length, irrespective of pipe size. The charts are based on the rational flow formula (Darcy) shown below. For higher pressures, see Piping Handbook by Crocker-King.

(2) Rational Flow Charts. The simplified rational flow formula (Darcy) is used for compressible fluids for all pressures. (See Equation 1 for method of calculation.)

## TABLE 3
## Representative Equivalent Length in Pipe Diameters (L/D) of Various Valves and Fittings[1]

| Item | Description of product | | Equivalent length in pipe diameters (L/D) |
|---|---|---|---|
| **Valves.** | | | |
| Conventional globe ............... | With no obstruction in flat. bevel or plug type seat. | Fully open | 340 |
| | With wing or pin guided disc. | Fully open | 450 |
| Y-pattern globe .................. | With stem 60 deg from run of pipe line. | Fully open | 175 |
| | With stem 45 deg from run of pipe line. | Fully open | 145 |
| Conventional angle ............... | With no obstruction in flat. bevel or plug type seat. | Fully open | 145 |
| | With wing or pin guided disc. | Fully open | 200 |
| Conventional wedge disc. double disc. or plug gate. | | Fully open | 13 |
| | | Three-quarters open | 35 |
| | | One-half open | 160 |
| | | One-quarter open | 900 |
| Pulp stock gate .................. | | Fully open | 17 |
| | | Three-quarters open | 50 |
| | | One-half open | 260 |
| | | One-quarter open | 1200 |
| Conduit pipe line gate ........... | | Fully open | 3[2] |
| Butterfly 6-in and larger ........ | | Fully open | 20 |
| Conventional swing check ......... | | 0.5[3].....Fully open | 135 |
| Clearway swing check ............. | | 0.5[3].....Fully open | 50 |
| Globe lift check or stop-check ... | | 2.0[3].....Fully open | Same as Conv. globe |
| Angle lift check or stop-check ... | | 2.0[3].....Fully open | Same as Conv. angle |
| Foot valves ...................... | With strainer and poppet lift-type disc. | 0.3[3].....Fully open | 420 |
| | With strainer and leather-hinged disc. | 0.4[3].....Fully open | 75 |
| In-line-ball check ............... | 2.5 vertical and 0.25 horizontal[3]. | ....Fully open | 150 |
| Straight-through cocks ........... | Rectangular plug port area equal to 100% of pipe area. | Fully open | 18 |
| Three-way cocks .................. | Rectangular plug port area equal to 80 percent of pipe area (fully open). | Flow straight through | 44 |
| | | Flow through branch | 140 |
| **Fittings:** | | | |
| 90 deg standard elbow ............ | | | 30 |
| 45 deg standard elbow ............ | | | 16 |
| 90 deg long radius elbow ......... | | | 20 |
| 90 deg street elbow .............. | | | 50 |
| 45 deg street elbow .............. | | | 26 |
| Square corner elbow .............. | | | 57 |
| Standard tee ..................... | With flow through run. | | 20 |
| | With flow through branch. | | 60 |
| Close pattern return bend ........ | | | 50 |

[1]Legitimate for all flow conditions except in laminar flow range where Reynolds no. is less than 1000.
[2]Exact equivalent length is equal to the length between flange faces of welding ends.
[3]Minimum calculated pressure drop psi across valve to provide sufficient flow to lift disc fully.

Note: For additional data see Table 7-7, Chapter 7, DM-3 series.

Equation: $$P_{100} = W^2 \frac{(0.000336f)\ V}{d^5} = C_1 \times C_2 \times V \qquad (1)$$

Where:

$P_{100}$ = pressure drop per 100 ft of equivalent length of pipe (psi)

$C_1 = W^2 10^{-9}$ (for values, see Figure 3)

$C_2 = \dfrac{336000f}{d^5}$ (for values, see Table 4)

W = rate of flow pounds per hour(pph)
f = friction factor
d = inside diameter of pipe (in)
V = specific volume of fluid (cu ft per lb) at average pressure in pipe

(3) Velocities. (See Table 5.)

Equation: $$V = \frac{3.06W}{d^2R} \qquad (2)$$

Where:

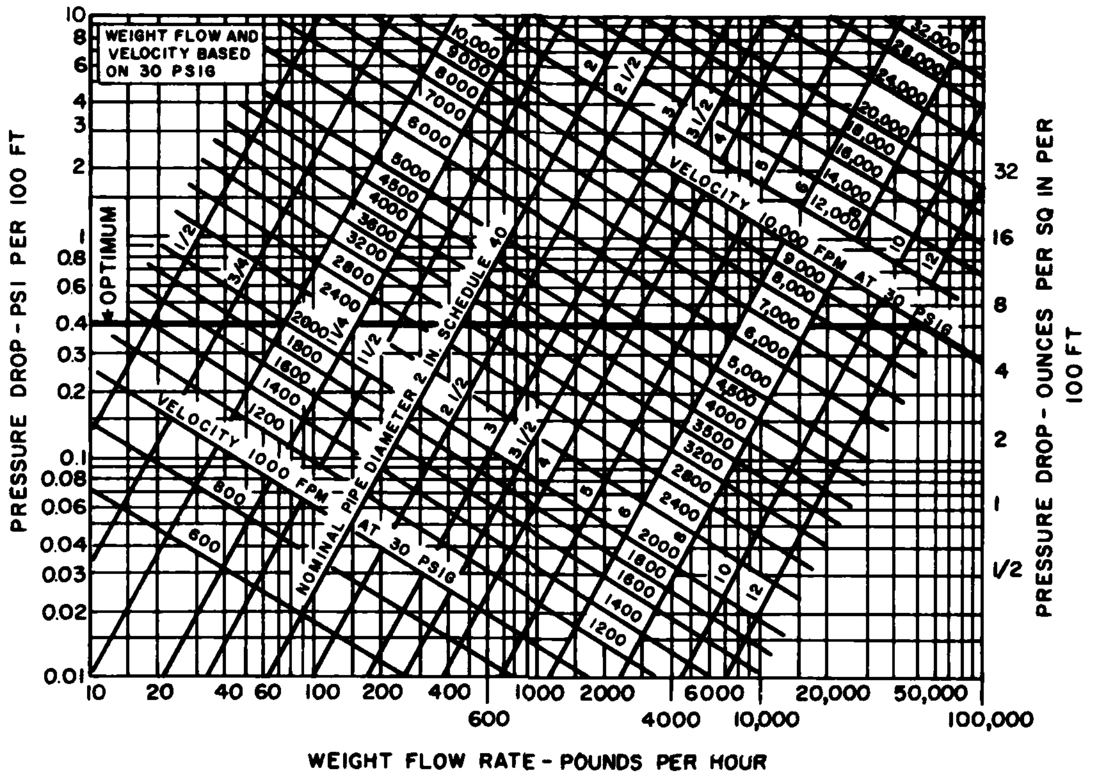
V = velocity of flow (fpm)
R = density (pcf)

(4) Steam Distribution Pressures. Steam pressure shall be governed by the highest pressure needed by the equipment served at the most remote location.

(a) The advantages of a low pressure system (under 15 psig): Low distribution loss; lower losses and trouble from leakage, traps, and venting; simplified pressure reduction at buildings; standard cast iron fittings; and low maintenance.

(b) The advantages of high pressure distribution (over 50 psig): Smaller pipe sizes; availability of steam for purposes other than for heating; and more flexibility in velocities and pressure drops.

(c) An economic analysis should be made to determine what pressure to use.

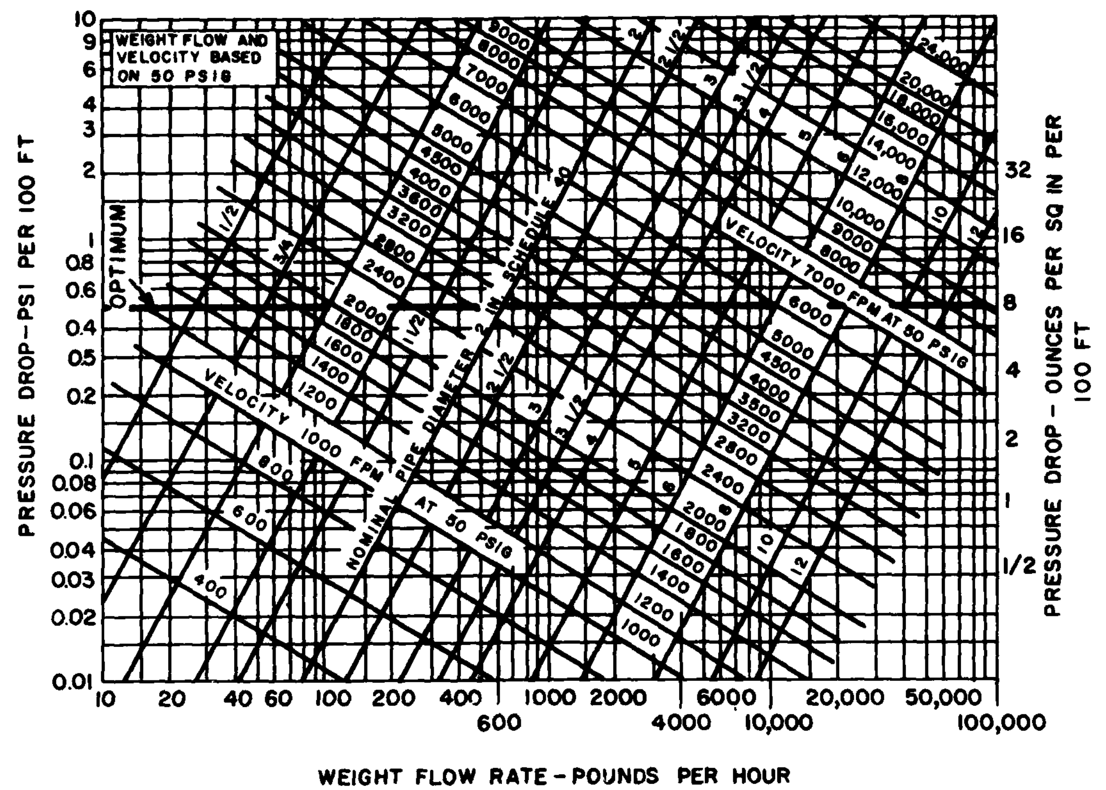



(MAY BE USED FOR STEAM PRESSURES FROM 23 TO 37 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

FIGURE 1a
Chart for Weight-Flow Rate

(5) Pressure Reducing Valves. Pressure reducing valves will be as follows:

(a) Selection of type. Double-ported, pilot-operated valves should be installed for large capacities, especially for inlet pressures above 125 pounds per square inch gage. Double-ported valves will not shut off completely on noload demand; therefore, single-seated valves must be used for such service. Reducing valves should not be installed according to pipe sizes, because oversized valves do not give satisfactory service. Select those valves to operate generally fully open, with ratings and reduction ratios as recommended by the manufacturer. A strainer and condensate drain should be installed ahead of the pressure-reducing valve. Because the volume of steam increases rapidly as the pressure is reduced, a reducing valve with increased outlet or expanding nozzle should be installed when the reduction ratio is more than 15 to 1. Cutout valves should be provided to isolate the pressure reducing valve to permit maintenance. Where the resulting superheated steam temperature is objectionable to the process on the low pressure side or the temperature-use limit of the equipment has been exceeded,




(MAY BE USED FOR STEAM PRESSURES FROM 40 TO 60 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

FIGURE 1b
Chart for Weight-Flow Rate

a desuperheater should be used to lower the steam temperature to that for saturation. A manual bypass should be provided for emergency operation when the pressure reducing valve is out of service. A pressure gage shall be provided on the low pressure side.

(b) Safety valves. One or more relief or safety valves should be provided on the low pressure side of each reducing valve in case the piping and/or equipment on the low pressure side do not meet the requirements of the full initial pressure. The combined discharge capacity of the relief valves shall be such that the pressure rating of the lower pressure piping and equipment will not be exceeded. For special conditions see ANSI B31.1 and ASHRAE Handbook and Product Directory.

(c) Capacity. Where steam requirements are relatively large (above approximately 3,000 pph) and subject to seasonal variation, two reducing valves should be installed in parallel, sized to pass 70 and 30 percent of maximum flow. During mild weather (spring and fall) the larger valve should be set at a slightly reduced pressure, so that it will remain

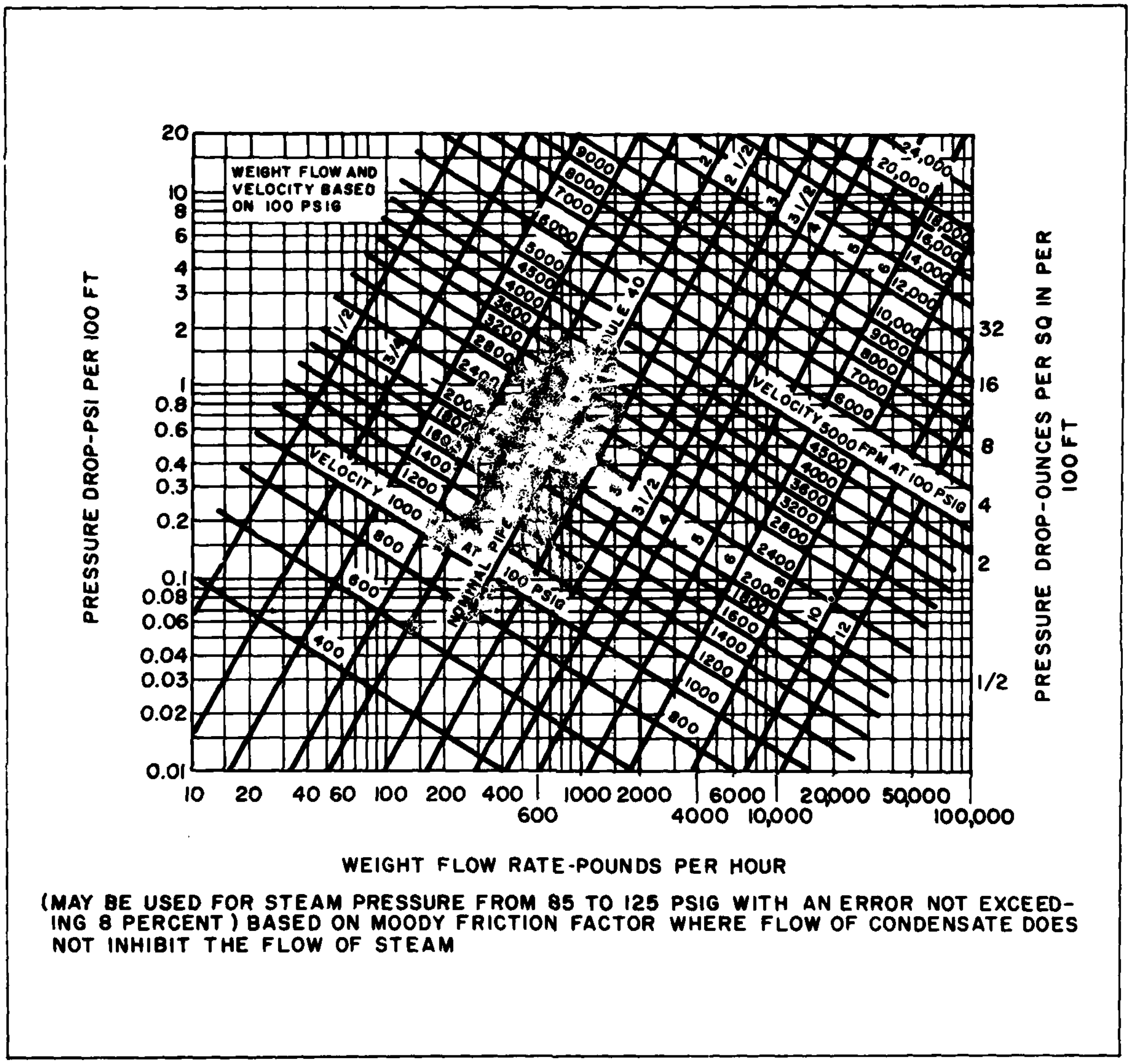
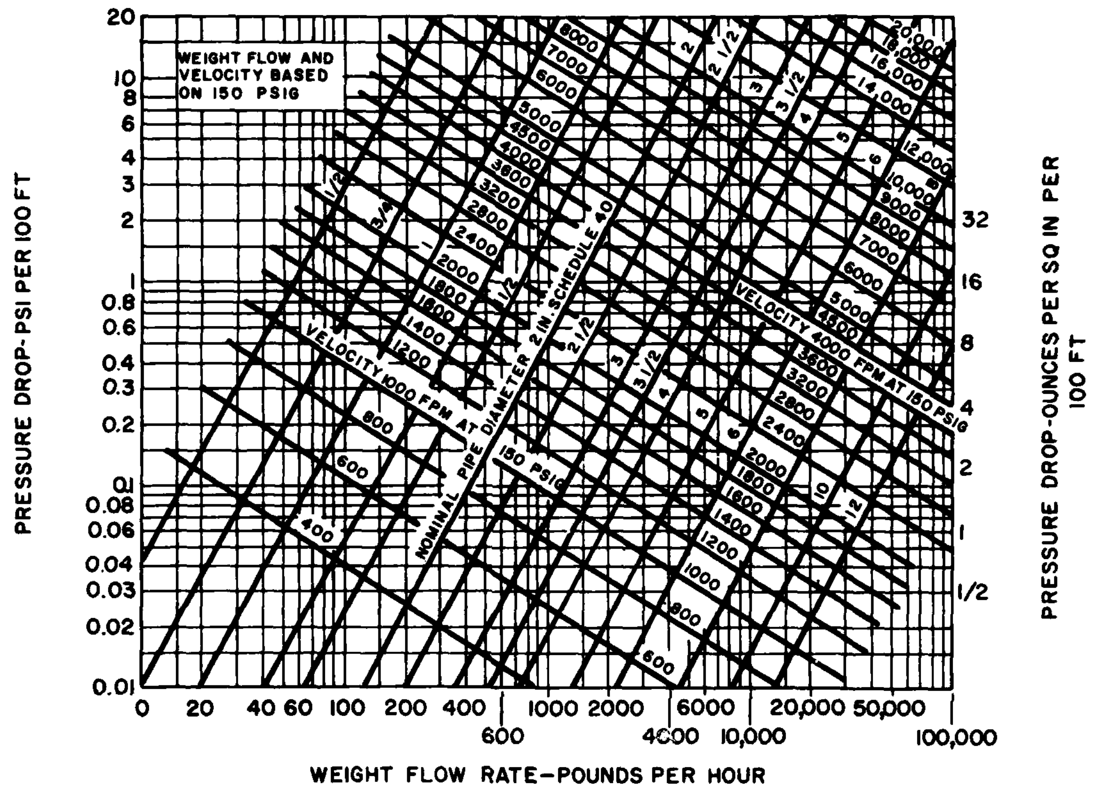



FIGURE 2a
Chart for Weight-Flow and Velocity of Steam

closed as long as the smaller valve can supply the demand. During the remainder of the heating season the valve settings are reversed to keep the smaller one closed except when the larger one is unable to supply the demand.

(6) Takeoffs from Mains. Takeoffs from mains to buildings should be at the top of mains and located at fixed points of the mains, at or near anchor points. Where a branch is short, valves at each takeoff are unnecessary, but where of considerable length or where several buildings are served, takeoffs should have valves.




(MAY BE USED FOR STEAM PRESSURES FROM 127 TO 180 PSIG WITH AN ERROR NOT EXCEEDING 8 PERCENT) BASED ON MOODY FRICTION FACTOR WHERE FLOW OF CONDENSATE DOES NOT INHIBIT THE FLOW OF STEAM.

FIGURE 2b
Chart for Weight-Flow Rate and Velocity of Steam

c. Condensate Returns. Condensate returns should be as follows:

(1) Return Piping. Size condensate trap piping to conform with 30 to 150 pounds per square inch steam piping in accordance with Tables 6a and 6b and interpolate these for other pressures.

(a) Discharge piping from condensate and heating pumps should be sized in accordance with pump capacities, which may be between 3.0 and 1.0 times the capacity of a steam system branch which they serve, depending on whether intermittently or continuously operated.

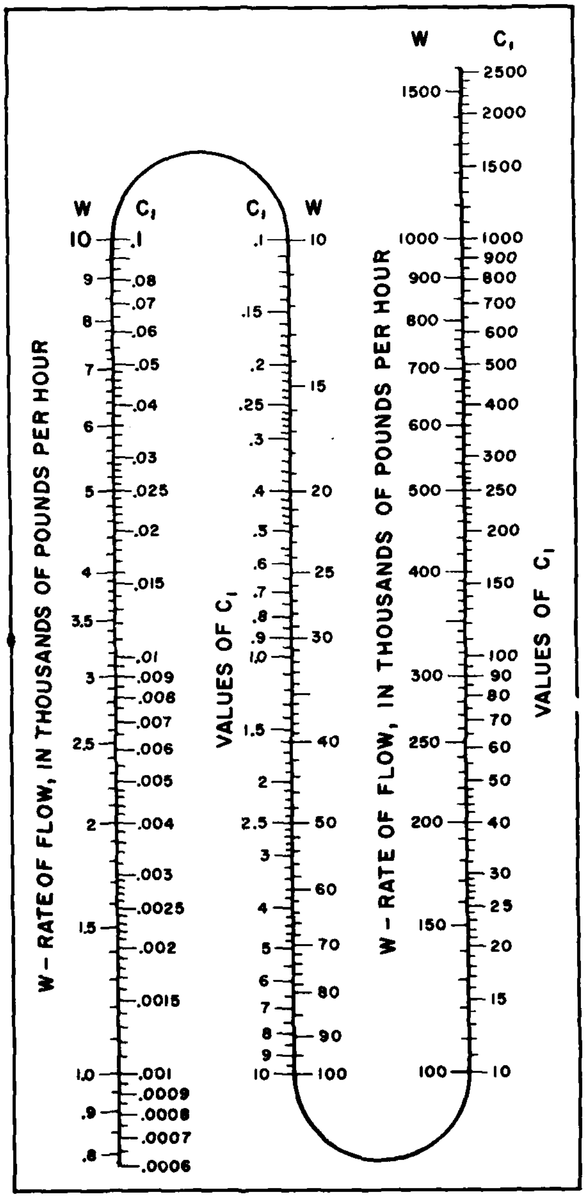



FIGURE 3
Values of $C_1$, Flow Factor in Equation 1

(b) Size common-pump discharge mains to serve the sum of their capacities. Use the Hydraulic Institute Pipe Friction Manual for steel pump discharge pipe sizing of new clean steel pipe, 6 feet per second maximum velocity, and a correction factor of 1.85 to provide for increased pressure drops when the pipe becomes dirty and rough with age. Friction plus static heads shall not exceed the pump characteristics of standard pump and receiver units.

(2) Condensate Return. Condensate return should be preferred if owning and operating costs of such a system is less than that of using and treating raw water for makeup. Factors favoring condensate return are:

(a) High concentration of steam usage
(b) Restriction on condensate disposal
(c) Favorable steam consuming facilities
(d) Favorable distribution conditions
(e) High raw water treatment costs
(f) Water treatment space unavailable
(g) High cost of raw water

d. High Temperature Water (HTW). High temperature water piping will be as follows:

(1) Sizing. Use pipe friction charts in ASHRAE Handbook and Product Directory.

(a) A reasonable, average velocity is approximately 5 feet per second and minimum allowable velocity 2 feet per second.

(b) The friction charts are based on the rational flow formula using clean pipe.

(2) Venting and draining. For methods of venting high points of distribution lines, see DM-3.3. Piping should have drainage means at low points.

e. Chilled Water. Use the standards of the Hydraulic Institute Pipe Friction Manual for sizing new clean pipe, unless water is renewed annually, in which case a correction factor of 1.41 for pressure drops should also be used. For recommended velocities, see DM-3 series.

f. Condenser Water. Use the standards of the Hydraulic Institute for pipe sizing, multiplying the pressure drop by a factor of 1.85 to correct for the increase of pipe roughness with age. For recommended velocities, see DM-3 series.

g. Fuel Gas. Apply criteria in DM-3.1 for sizing pipe inside buildings. Use Figure 4 for low pressure gas and Figure 5 for high pressure gas in sizing distribution piping. Exterior distribution piping usually stops 5 feet outside of buildings.

h. Compressed Air. For criteria on distribution piping, see DM-3 series.

## TABLE 4
### Values of $C_2$, Flow Factor in Equation 1

| Nominal pipe size (in) | Schedule no. | Value of $C_2$ |
|---|---|---|
| 1/8 ......... | 40 s | 7 920 000. |
| | 80 x | 26 200 000. |
| 1/4 ......... | 40 s | 1 590 000. |
| | 80 x | 4 290 000. |
| 3/8 ......... | 40 s | 319 000. |
| | 80 x | 718 000. |
| 1/2 ......... | 40 s | 93 500. |
| | 80 x | 186 100. |
| | 160 | 4 300 000. |
| | xx | 11 180 000. |
| 3/4 ......... | 40 s | 21 200. |
| | 80 x | 36 900. |
| | 160 | 100 100. |
| | xx | 627 000. |
| 1 .......... | 40 s | 5 950. |
| | 80 x | 9 640. |
| | 160 | 22 500. |
| | xx | 114 100. |
| 1-1/4 ...... | 40 s | 1 408. |
| | 80 x | 2 110. |
| | 160 | 3 490. |
| | xx | 13 640. |
| 1-1/2 ...... | 40 s | 627. |
| | 80 x | 904. |
| | 160 | 1 656. |
| | xx | 4 630. |
| 2 .......... | 40 s | 169. |
| | 80 x | 236. |
| | 160 | 488. |
| | xx | 899. |
| 2-1/2 ...... | 40 s | 66.7 |
| | 80 x | 91.8 |
| | 160 | 146.3 |
| | xx | 380.0 |
| 3 .......... | 40 s | 21.4 |
| | 80 x | 28.7 |
| | 160 | 48.3 |
| | xx | 96.6 |
| 3-1/2 ...... | 40 s | 10.0 |
| | 80 x | 37.7 |
| 4 .......... | 40 s | 5.17 |
| | 80 x | 6.75 |
| | 120 | 8.94 |
| | 160 | 11.80 |
| | xx | 18.59 |
| 5 .......... | 40 s | 1.59 |
| | 80 x | 2.04 |
| | 120 | 2.69 |
| | 160 | 3.59 |
| | xx | 4.93 |
| 6 .......... | 40 s | 0.610 |
| | 80 x | 0.798 |
| | 120 | 1.015 |
| | 160 | 1.376 |
| | xx | 1.861 |
| 8 .......... | 20 | 0.133 |
| | 30 | 0.135 |
| | 40 s | 0.146 |
| | 60 | 0.163 |
| | 80 x | 0.185 |
| | 100 | 0.211 |
| | 120 | 0.252 |
| | 140 | 0.289 |
| | xx | 0.317 |
| | 160 | 0.333 |
| 10 .......... | 20 | 0.039 7 |
| | 30 | 0.042 1 |
| | 40 s | 0.044 7 |
| | 60 x | 0.051 4 |
| | 80 | 0.056 9 |
| | 100 | 0.066 1 |
| | 120 | 0.075 3 |
| | 140 | 0.090 5 |
| | 160 | 0.105 2 |
| 12 ......... | 20 | 0.015 7 |
| | 30 | 0.016 8 |
| | s | 0.017 5 |
| | 40 | 0.018 0 |
| | x | 0.019 5 |
| | 60 | 0.020 6 |
| | 80 | 0.023 1 |
| | 100 | 0.026 7 |
| | 120 | 0.031 0 |
| | 140 | 0.035 0 |
| | 160 | 0.042 3 |
| 14 ......... | 10 | 0.009 49 |
| | 20 | 0.009 96 |
| | 30 s | 0.010 46 |
| | 40 | 0.010 99 |
| | x | 0.011 55 |
| | 60 | 0.012 44 |
| | 80 | 0.014 16 |
| | 100 | 0.016 57 |
| | 120 | 0.018 98 |
| | 140 | 0.021 8 |
| | 160 | 0.025 2 |
| 16 ......... | 10 | 0.004 63 |
| | 20 | 0.004 21 |
| | 30 s | 0.005 04 |
| | 40 x | 0.005 49 |
| | 60 | 0.006 12 |
| | 80 | 0.007 00 |
| | 100 | 0.008 04 |
| | 120 | 0.009 26 |
| | 140 | 0.010 99 |
| | 160 | 0.012 44 |
| 18 ......... | 10 | 0.002 47 |
| | 20 | 0.002 56 |
| | s | 0.002 66 |
| | 30 | 0.002 76 |
| | x | 0.002 87 |
| | 40 | 0.002 98 |
| | 60 | 0.003 35 |
| | 80 | 0.003 76 |
| | 100 | 0.004 35 |
| | 120 | 0.005 04 |
| | 140 | 0.005 73 |
| | 160 | 0.006 69 |
| 20 ......... | 10 | 0.001 41 |
| | 20 s | 0.001 50 |
| | 30 x | 0.001 61 |
| | 40 | 0.001 69 |
| | 60 | 0.001 91 |
| | 80 | 0.002 17 |
| | 100 | 0.002 51 |
| | 120 | 0.002 87 |
| | 140 | 0.003 35 |
| | 160 | 0.003 85 |
| 24 ......... | 10 | 0.000 534 |
| | 20 s | 0.000 565 |
| | x | 0.000 597 |
| | 30 | 0.000 614 |
| | 40 | 0.000 651 |
| | 60 | 0.000 741 |
| | 80 | 0.000 835 |
| | 100 | 0.000 972 |
| | 120 | 0.001 119 |
| | 140 | 0.001 274 |
| | 160 | 0.001 478 |

NOTE.--The letters s, x, and xx in the columns of Schedule no. indicate Standard, Extra Strong, and Double Extra Strong pipe respectively.

TABLE 5
Reasonable Velocities for Flow of Steam in Pipes

| Condition of steam | Pressure (psig) | Service | Reasonable velocity[1] (fpm) |
|---|---|---|---|
| Saturated...... | Vacuum....... | Turbine exhaust..... | Up to 18,000 |
| | 0 to 25...... | Heating............. | 4,000 to 6,000 |
| | 25 and up.... | Steam distribution.. | 6,000 to 10,000 |
| | 125 and up... | Underground steam distribution....... | Up to 20,000 |
| Superheated.... | 200 and up... | Boiler and turbine leads.............. | 7,000 to 20,000 |

[1]Velocities should be below those which would produce excessive noise in areas where that would be objectionable. Velocity limitations need not apply in uninhabited areas.

i. Acetylene and Oxygen. For criteria on piping and distribution, use Land Operational Facilities, NAVFAC DM-24 series.

2. PIPING SPECIFICATIONS AND CODES. Piping specifications and codes will be as follows:

a. Steam Supply and Condensate Return. Piping shall conform to Standard Code for Pressure Piping B31.1, Power Piping (American National Standards Institute), except for underground prefabricated or pre-engineered type systems, in which case the entire system shall conform to NAVFAC Guide Specification TS-15705. If a plastic pipe condensate return system is used, it also shall conform to NAVFAC Guide Specification TS-15707.

b. High Temperature Water. Piping specifications and codes, except for underground prefabricated or pre-engineered types, in which case the entire system shall conform to NAVFAC Guide Specification TS-15705 for high temperature water will be as follows:

(1) Piping. HTW piping (450° F maximum) shall conform to ANSI B31.1, Standard Code for Pressure Piping, Power Piping.

(2) Joints. Use welded joints throughout. Threaded joints are not permitted. Hold flanged joints to a minimum and use ferrous alloy gaskets in such joints. Avoid the use of copper and brass pipe.

TABLE 6(a)
Return Pipe Capacities for 30 psig Steam Systems[1]
(Capacity Expressed in pph)

| Pipe size (in) | Drop in pressure (psi per 100 ft in length) 1/8 | 1/4 | 1/2 | 3/4 | 1 |
|---|---|---|---|---|---|
| 3/4 ............ | 115 | 170 | 245 | 308 | 365 |
| 1 ................ | 230 | 340 | 490 | 615 | 730 |
| 1-1/4 ............ | 485 | 710 | 1,025 | 1,290 | 1,530 |
| 1-1/2 ............ | 790 | 1,160 | 1,670 | 2,100 | 2,500 |
| 2 ................ | 1,580 | 2,360 | 3,400 | 4,300 | 5,050 |
| 2-1/2 ............ | 2,650 | 3,900 | 5,600 | 7,100 | 8,400 |
| 3 ................ | 4,850 | 7,100 | 10,300 | 12,900 | 15,300 |
| 3-1/2 ............ | 7,200 | 10,600 | 15,300 | 19,200 | 22,800 |
| 4 ................ | 10,200 | 15,000 | 21,600 | 27,000 | 32,300 |
| 5 ................ | 19,000 | 27,800 | 40,300 | 55,500 | 60,000 |
| 6 ................ | 31,000 | 45,500 | 65,500 | 83,000 | 98,000 |

[1]The above table is based on steam at pressure of 0 to 4 psig.

TABLE 6(b)
Return Pipe Capacities for 150-psig Steam Systems[1]
(Capacity Expressed in pph)

| Pipe size (in) | Drop in pressure (psi per 100 ft in length) 1/8 | 1/4 | 1/2 | 3/4 | 1 | 2 |
|---|---|---|---|---|---|---|
| 3/4 ............ | 156 | 232 | 360 | 465 | 560 | 890 |
| 1 ................ | 313 | 462 | 690 | 910 | 1,120 | 1,780 |
| 1-1/4 ............ | 650 | 960 | 1,500 | 1,950 | 2,330 | 3,700 |
| 1-1/2 ............ | 1,070 | 1,580 | 2,460 | 3,160 | 3,800 | 6,100 |
| 2 ................ | 2,160 | 3,300 | 4,950 | 6,400 | 7,700 | 12,300 |
| 2-1/2 ............ | 3,600 | 5,350 | 8,200 | 10,700 | 12,800 | 20,400 |
| 3 ................ | 6,500 | 9,600 | 15,000 | 19,500 | 23,300 | 37,200 |
| 3-1/2 ............ | 9,600 | 14,400 | 22,300 | 28,700 | 34,500 | 55,000 |
| 4 ................ | 13,700 | 20,500 | 31,600 | 40,500 | 49,200 | 78,500 |
| 5 ................ | 25,600 | 38,100 | 58,500 | 76,000 | 91,500 | 146,000 |
| 6 ................ | 42,000 | 62,500 | 96,000 | 125,000 | 150,000 | 238,000 |

[1]The above table is based on steam at pressure of 1 to 20 psig.

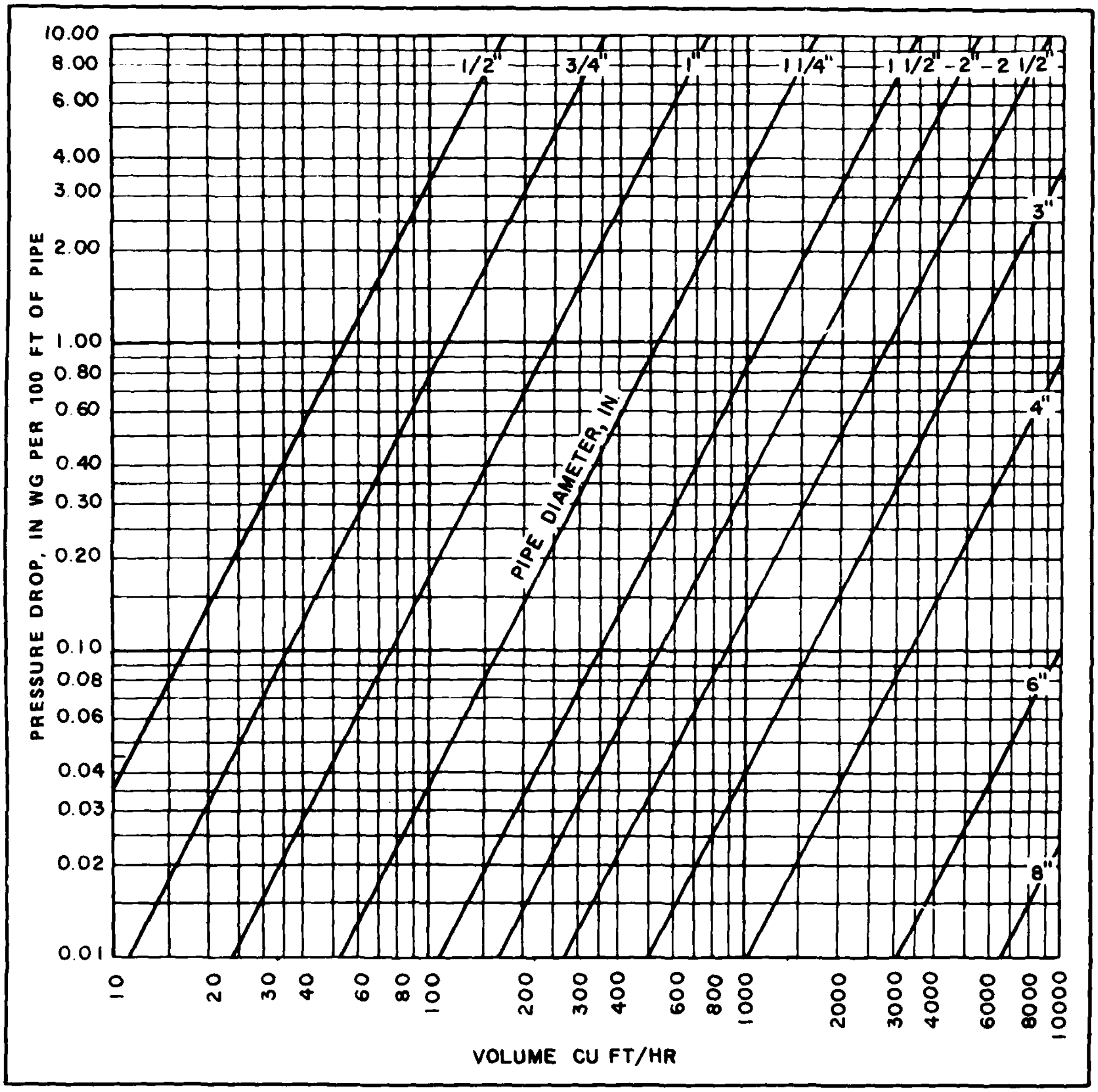



FIGURE 4
Low Pressure Gas Chart

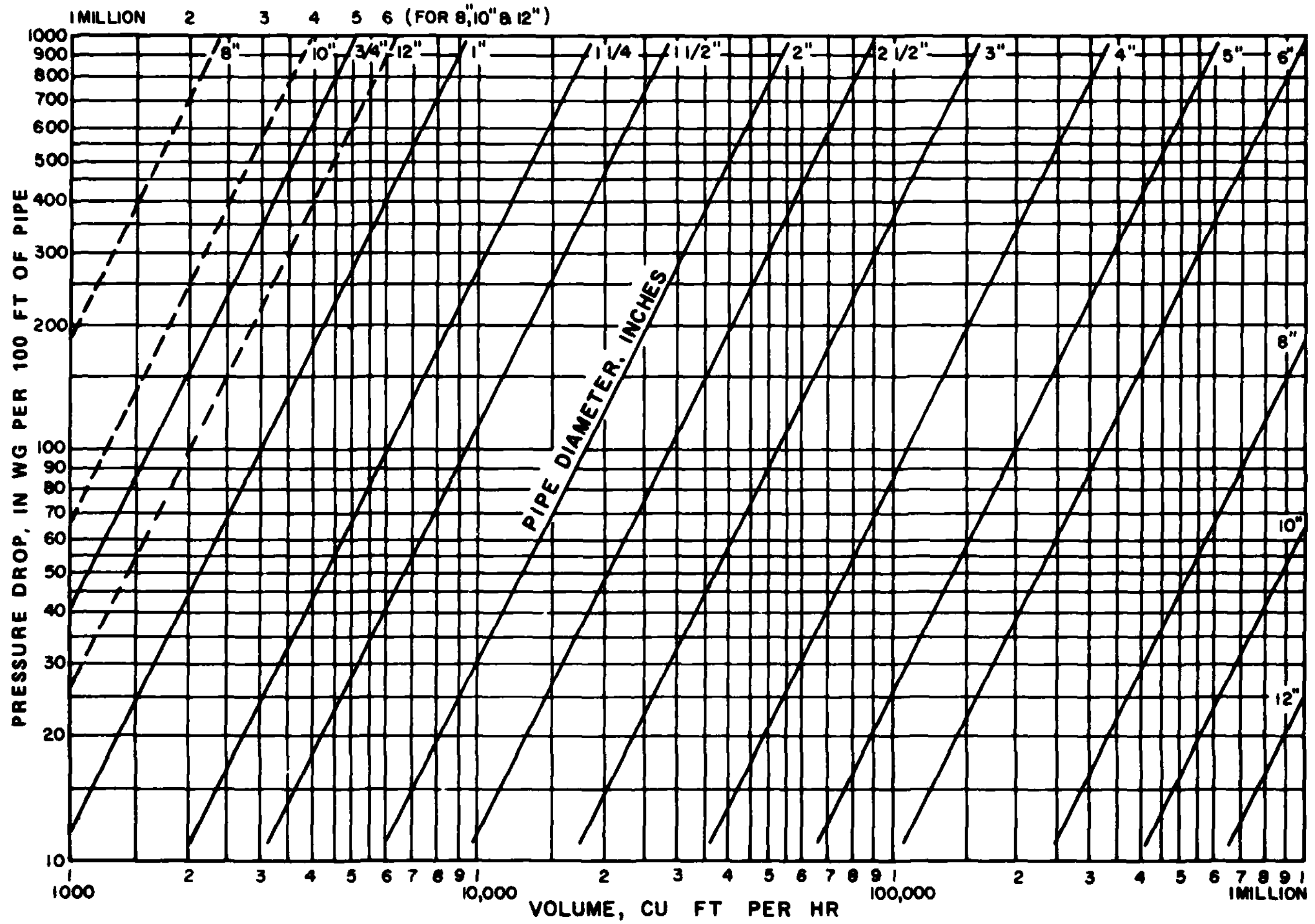



FIGURE 5

HIGH PRESSURE GAS CHART simplifies design of piping by indicating required diameter, maximum rate of flow, permissible pressure drop, initial pressure, or final pressure when the rest of these values are known. The chart is based on the Weymouth formula for rate of flow in cubic feet of gas per hour. (Chart based upon following conditions: Gas at 60 degrees F, atmospheric pressure, and specific gravity of 0.60, with air = 1.0)

(3) Valves. All valves shall have cast steel bodies with stainless steel trim (no bronze trim). All valves shall be capable of being repacked under operating pressures. Use gate valves only as shutoff or isolation valves.

c. Fuel Gas and Compressed Air. Piping shall conform to ANSI B31.1 Power Piping, ANSI B31.2 Fuel Gas Piping; and ANSI B32.8, Gas Transmission and Distribution Piping Systems. Provide earthquake shut off valves in gas supply piping outside of each building served in earthquake zones. In addition, flexible connections should be provided. Gas piping and appurtenances from point of connection with existing system to a point approximately 5 feet from the building shall conform to NAVFAC Guide Specification TS-02711, Outside Gas System.

d. Chilled and Condenser Water. Use Schedule 40 steel pipe in 10-inch sizes and smaller, use 0.5-inch wall thickness steel pipe for 12-inch size and larger.

3. FLEXIBILITY AND ALLOWABLE BENDING STRESSES. Piping used must be as follows:

a. Thermal Expansion of Pipe. Pipe lengthens with temperature increases (such as between installation and operating temperatures) as indicated in Table 7.

b. Control of Expansion. Wherever possible, provide for expansions of pipes by changes in directions of pipe runs or by the use of expansion bends.

(1) Expansion Joints. Only where space restrictions prevent the above provisions shall expansion joints be installed, and then only in accessible locations.

(2) Branch Lines. Where practicable, piping should be designed to provide for expansions of branch lines inside buildings and should have no effect on mains.

c. Expansion Bends. Bends should be factory fabricated.

(1) Loop Sections. Loops should be furnished in sections to facilitate delivery and handling.

(2) Anchors. A reasonable distance between anchors for expansion loops is 200 feet.

(3) Cold Springing. Cold springing may be used in installations but no design stress relief shall be allowed for it. For credit permitted in thrust and moments, refer to ANSI B31.1.

d. Expansion Joints. These joints shall be one of the types below.

(1) Mechanical Slip Joint. An externally guided joint designed for repacking under operating pressures. Maximum traverses of piping in expansion joints should be held under 8 inches.

TABLE 7
Expansion of Pipe in Inches Per 100 Feet of Length for Temperatures Shown

| Temperature (degree F) | Material | | Temperature (degree F) | Material | |
|---|---|---|---|---|---|
| | Steel | Copper | | Steel | Copper |
| 0 ..... | 0 | 0 | 390 ..... | 3.156 | 4.532 |
| 10 ..... | 0.075 | 0.111 | 400 ..... | 3.245 | 4.653 |
| 20 ..... | 0.149 | 0.222 | 410 ..... | 3.334 | 4.777 |
| 30 ..... | 0.224 | 0.333 | 420 ..... | 3.423 | 4.899 |
| 40 ..... | 0.299 | 0.444 | 430 ..... | 3.513 | 5.023 |
| 50 ..... | 0.374 | 0.556 | 440 ..... | 3.603 | 5.145 |
| 60 ..... | 0.449 | 0.668 | 450 ..... | 3.695 | 5.269 |
| 70 ..... | 0.525 | 0.780 | 460 ..... | 3.785 | 5.394 |
| 80 ..... | 0.601 | 0.893 | 470 ..... | 3.874 | 5.519 |
| 90 ..... | 0.678 | 1.006 | 480 ..... | 3.962 | 5.643 |
| 100 ..... | 0.755 | 1.119 | 490 ..... | 4.055 | 5.767 |
| 110 ..... | 0.831 | 1.233 | 500 ..... | 4.418 | 5.892 |
| 120 ..... | 0.909 | 1.346 | 520 ..... | 4.334 | 6.144 |
| 130 ..... | 0.987 | 1.460 | 540 ..... | 4.524 | 6.396 |
| 140 ..... | 1.066 | 1.575 | 560 ..... | 4.174 | 6.650 |
| 150 ..... | 1.145 | 1.690 | 580 ..... | 4.903 | 6.905 |
| 160 ..... | 1.224 | 1.805 | 600 ..... | 5.096 | 7.160 |
| 170 ..... | 1.304 | 1.919 | 620 ..... | 5.291 | 7.417 |
| 180 ..... | 1.384 | 2.035 | 640 ..... | 5.486 | 7.677 |
| 190 ..... | 1.464 | 2.152 | 660 ..... | 5.583 | 7.938 |
| 200 ..... | 1.545 | 2.268 | 680 ..... | 5.882 | 8.197 |
| 210 ..... | 1.626 | 2.384 | 700 ..... | 6.083 | 8.460 |
| 220 ..... | 1.708 | 2.501 | 720 ..... | 6.284 | 8.722 |
| 230 ..... | 1.791 | 2.618 | 740 ..... | 6.488 | 8.988 |
| 240 ..... | 1.872 | 2.736 | 760 ..... | 6.692 | 9.252 |
| 250 ..... | 1.955 | 2.854 | 780 ..... | 6.899 | 9.519 |
| 260 ..... | 2.038 | 2.971 | 800 ..... | 7.102 | 9.783 |
| 270 ..... | 2.132 | 3.089 | 820 ..... | 7.318 | 10.056 |
| 280 ..... | 2.207 | 3.208 | 840 ..... | 7.529 | 10.327 |
| 290 ..... | 2.291 | 3.327 | 860 ..... | 7.741 | 10.598 |
| 300 ..... | 2.376 | 3.446 | 880 ..... | 7.956 | 10.872 |
| 310 ..... | 2.460 | 3.565 | 900 ..... | 8.172 | 11.144 |
| 320 ..... | 2.547 | 3.685 | 920 ..... | 8.389 | 11.420 |
| 330 ..... | 2.632 | 3.805 | 940 ..... | 8.608 | 11.696 |
| 340 ..... | 2.718 | 3.926 | 960 ..... | 8.830 | 11.973 |
| 350 ..... | 2.805 | 4.050 | 980 ..... | 9.052 | 12.253 |
| 360 ..... | 2.892 | 4.167 | 1.000 ..... | 9.275 | 12.532 |
| 370 ..... | 2.980 | 4.289 | 1.100 ..... | 10.042 | 13.950 |
| 380 ..... | 3.069 | 4.411 | 1.200 ..... | 11.598 | 15.397 |

(2) Bellows Type Joint. Use these joints for thermal expansion with stainless steel bellows, guided and installed according to manufacturer instructions. Bellows or corrugations for absorbing vibrations or mechanical movements at ambient temperatures may be made of copper or other materials suitable for the job conditions. A maximum travel of 4 inches shall be allowed for this type.

(3) Flexible Ball Joints. These joints should be installed according to manufacturer instructions.

e. Flexibility Analysis. See Section 6 of ANSI B31.1 for expansion and flexibility criteria and allowable stresses and reactions.

(1) For methods of analyzing stresses in piping systems, use piping handbooks and publications of pipe and welding pipe fitting manufacturers. These manufacturers also supply calculation forms and charts.

(2) Keep calculated pipe stresses under those allowed by ANSI B31.1.

4. DRAINAGE PROVISIONS. Drainage provisions must conform to requirements listed below.

a. Pitch. The use and surrounding terrain will affect the pitch of piping as below.

(1) Steam Piping. Piping shall be pitched down at a minimum of 3 inches per 100 feet of length in the direction of steam flow and condensate flow within a steam pipe.

(2) Underground Piping. Where the ground surface slopes in the opposite direction to steam piping, step up underground piping in vertical risers at drip points in manholes and pitch them down to the next drip point. This method should be used also for all very long horizontal runs, above or below ground, to keep piping within a reasonable range of elevations.

(3) Counter-flow Conditions. Where counter-flow of condensate within the steam pipe may occur in a portion of a pipeline because the stepped construction cannot be built, or because of steam flow reversal in a loop system, that portion shall be pitched up in the direction of steam flow a minimum of 6 inches per 100 feet and pipe diameters shall be increased by one standard pipe size.

(4) Compressed Air and Fuel Gas Lines. Pitch compressed air and gas piping as for steam piping.

(5) Pumped Water Pipe. Pitch these pipes (condensate, HTW, CHW, or condenser water) up or down in direction of flow. Drain valves should be placed at all low points.

b. Drips and Vents. Drips and vents will be as follows:

(1) Drip Legs. These legs should be provided to collect condensate from steam piping and compressed air piping for removal by automatic moisture traps, or by manual drain valves for compressed air piping when practicable. Drip legs should be at low points, at the bottom of all risers and at intervals of approximately 200-300 feet for horizontally pitched pipe where a trap is accessible, and not over 500 feet for buried underground pipe systems.

(2) Water Piping. Piping, especially high temperature water piping, should be vented at distribution piping high points.

c. Condensate Piping. Condensate piping will be as follows:

(1) Drip Traps. Furnish a complete system of drip traps and piping to drain all steam piping of condensate from drip legs. Drip piping to traps shall be the same weight and material as the drained pipings.

(2) Traps. A trap may be discharged through a check valve into the pumped condensate line if pressure in the trap discharge line exceeds the back pressure in the pumped condensate line during standby time of an intermittently operated pump. Preferably, a condensate line from a trap should run separately to a gravity condensate return main or to a nearby flash tank. (See ASHRAE Handbook & Product Directory for flash tank details and specific trap applications.)

(3) Traps Discharge Piping. This piping shall be pitched down at a minimum of 3 inches per 100 feet to the collection tank of a condensate pump set or to a gravity return unless there is sufficient pressure in a steam line to overcome the friction and static head in the line whether level or pitched up.

(4) Drains to Sewer. If unjustifiable to return drips to a condensate system, they may be drained as waste to a sewer. If the temperature exceeds sewer limitations, condensate must be cooled in a sump or by other means. Disposal of condensate from steam systems along waterfront, or under piers warrants special consideration and shall be determined on a case-by-case basis.

5. ANCHORS AND SUPPORTS. Anchors and supports must be as follows:

a. Anchors. Anchors for pipe support should be as is indicated below.

(1) Location. Locate anchors at takeoffs from mains and other necessary points to contain pipeline expansions. If possible, anchors should be located in buildings, tunnels, and manholes with suitable access.

(2) Specification. All anchors shall be appropriately designed and located in accordance with ANSI B31 Codes for Pressure Piping.

(3) Strength. Anchors shall be strong enough to withstand expansion reactions. With expansion joints, the additional end reactions due to internal fluid pressure should be considered.

(4) Guying. On aboveground systems at high elevations, the ends of structural steel shapes anchoring pipes to poles should be guyed parallel to the pipeline in both directions to concrete deadmen by wire rope and turnbuckles if necessary.

(5) Embedding. In underground concrete trenches, the ends of structural steel shapes anchoring a pipe may be embedded in the trench walls or floors.

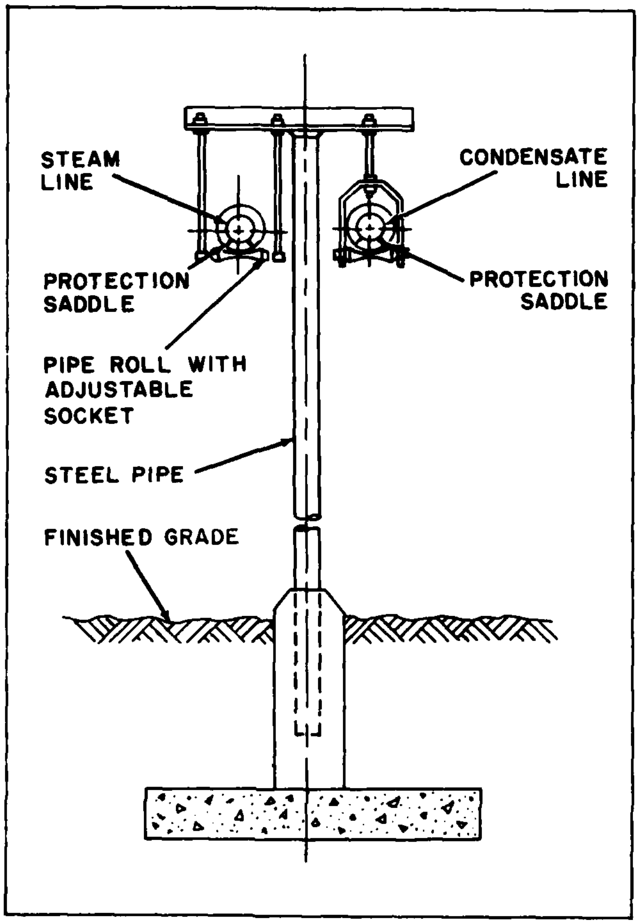



FIGURE 6
Aboveground Pipe Supports

b. <u>Supports</u>. These shall conform to ANSI B31 Codes for Pressure Piping.

(1) Low Elevations. For aboveground systems at low elevations, concrete pedestals, steel frames, or treated wood frames may be used and spaced as required depending on pipe sizes.

(2) High Elevations. At higher elevations aboveground, pipelines may be supported on wood, steel pipe, H-section steel, reinforced concrete, prestressed concrete, poles with crossarms, or steel frameworks fitted with rollers and insulation saddles. (See Figure 6 for some types of supports.) Details of design with vary depending on site conditions.

(3) Long Spans. When long spans are necessary, cable-suspension or catenary systems may be used with supports up to 50 feet on center.

(4) Underground Conduits. Supports for underground conduits should be approved types of manufacturers' standard designs.

## Section 4. DISTRIBUTION METHODS

1. SERVICE AND LOADS. Determine from Section 2, the services, such as steam, hot temperature water, compressed air, and others, required for each load center or building, the load demands for each service, and the capacity of a source of central plant for each service. (See Section 2 for fluid conditions inside service lines, for sizing pipes for these conditions, and for the required capacities.)

2. DISTRIBUTION CIRCUITS. Select a type of circuit which is economical, easy to operate, balance and control, and is suitable for a particular project terrain. (See Table 8 for types of distribution circuits.) Note that types easiest to balance and control are those where pressure and temperature differences are fairly constant between equipment supply and return branches.

3. DISTRIBUTION ROUTES. Distribution routes for piping must conform to the following criteria.

a. Preliminary Planning. The following factors must be considered in preliminary planning.

(1) Alternate Routes. Consider several alternate preliminary but direct routes for each service pipeline from its source to delivery load centers, allowing for future expansion.

(2) Pressure Drop. From the total allowable pressure drop and ultimate length of a line, determine the pressure drop per 100 feet. Note the maximum flow between each load center and size the different pipeline sections accordingly.

(3) Obstacles. From a field survey, note all obstacles for each route.

(4) Economy. Select the route considered technically and economically best justified; make full use of building basements, crawl spaces, and attics including connecting corridors between buildings, and existing tunnels, and concrete trenches. However, high pressure fuel gas, steam, and HTW piping inside buildings should be avoided where fire or safety is a consideration.

(5) Future Buildings. These buildings should be considered and a route planned to supply them easily.

b. Piping Layouts. Piping must be planned and positioned as below.

(1) Parallel Piping. Determine what lines between the same points should parallel each other (such as supply and return) or be separated (such as steam from chilled water). The minimum clearance between pipe conduits in the same trench should be 6 inches.

(2) Location. Determine locations of expansion bends or loops, anchors, takeoffs, and drip points.

TABLE 8
Types of Distribution Circuits

| State of fluid | Passage of fluid through equipment | Supply branch | Return branch | Comments |
|---|---|---|---|---|
| Compressible, such as steam, fuel gas, compressed air, etc. | Broken, due to change of state or to consumption within equipment. | From supply trunk piping. | To direct return trunk piping for condensate from steam. | Pressure and temperature differences between supply and return branches decrease as distance from source increases, but these changes are relatively minor. |
| Noncompressible such as water, fuel oil, etc. | Continuous ...... | From supply trunk piping. | To direct return trunk piping. | Pressure and temperature differences between supply and return branches decrease as distance from source increases, but these changes are relatively large. |
| | | | To reversed return trunk line. | Pressure and temperature differences between all supply and return branches are approximately same. |
| | | From supply loop. | To supply loop, after supply branch. | Pressure and temperature differences between all supply and return branches approximately same but supply loop pressure and temperature are reduced after each set of supply and return branches. |
| | Broken, as in once-through cooling system. | From supply trunk piping. | To return trunk piping. | Pressure and temperature differences between supply and return branches are approximately same. |

(3) Map. Lay out each piping on a scaled contour map of a site and on a profile drawing along the route, locating all obstructions and interferences, such as streams, roads, railroads, buried tunnels, concrete trenches, drainage piping, sewers, water piping, electrical conduits, and other service piping.

c. Underground. Use only approved and certified conduit systems for steam, condensate and HTW, and procure and install in accordance with the requirements of TS-15705 Underground Heat Distribution Systems (prefabricated or pre-engineered type). The Federal Agency Committee for Underground Heat Distribution Systems approves and certifies the various types of conduit systems, i.e., drainable and dryable (pressure testable), sectionalized, prefabricated (non pressure testable) and poured-in-place granular insulation type conduit systems.

(1) Site Classification. The selection of the conduit system type shall be based on the underground water conditions at the project site as defined in TS-15705 for Class A, B, C, or D application corresponding to underground water conditions ranging from severe to mild, respectively. The letter of certification contained in the conduit system brochure stipulates the approved site classification.

(2) Design Responsibilities. The project design agency is responsible for providing the following information prior to project bidding:

(a) Defining site conditions for underground water classification (A, B, C or D), soil corrosiveness, soil pH if less than 5.0, and potential soil load bearing problems.

(b) Determining the general layout and essential characteristics of the system such as system media, maximum operating temperature and pressure, location of manholes, and branch runouts.

(c) Designing special elements of the system as required.

(d) Calculating the maximum heat loss per lineal foot of the conduit in accordance with the procedures outlined in TS-15705.

(3) RTRP condensate lines should be used whenever economically feasible in lieu of extra strong steel for longer service life. Procure and install RTRP condensate piping in accordance with TS-15707. Special care should be taken in the design of steam drip connections to protect the RTRP piping from live steam. Insulate condensate piping only when a life cycle cost analysis indicates a payback in energy savings, or where needed for personnel protection.

d. Choice of Route. Except in congested and vulnerable areas, choose aboveground routes for heat distribution systems. Otherwise, adapt site conditions to comparative advantages of going above- or underground as stated in the following:

| Aboveground | Underground |
|---|---|
| Lower first cost | Less vulnerable target |
| Less maintenance | Less obstruction to aboveground traffic |
| Easy detection of failure | Less unsightly |
| Higher continuous operating efficiency | Freeze protected when buried |
| Longer life | Less heat gain in chilled condenser water piping |

e. Route Types. Distribution piping may be run through buildings, aboveground, or underground.

(1) Through Buildings. Piping is most economical and easiest to maintain, however, safety or fire hazard considerations may curtail this method of routing.

(2) Aboveground Overhead Piping. Piping may be located as little as 12 inches or as much as 22 feet above grade.

(a) A 14- to 16-foot clearance is usually required for automobile and truck traffic, and a 22-foot height for railroad cars.

(b) See NAVFAC Specification 53Y (latest revision) and NAVFAC Guide Specification TS-15P28 (latest revision) for aboveground piping systems for heat distribution, including insulation, jackets, etc.

(3) Buried Piping. For buried piping routes, the following criteria apply:

(a) Compressed air, and gas piping generally require no insulation, but they should be shop coated and wrapped, and tested and handled in accordance with NAVFAC Guide Specifications TS-02711, outside gas systems, and TS-15411, compressed air systems (non-breathing air type). Provide for testing of coverings by electrical flow detectors.

(b) All buried piping and conduits shall be protected by laying them under a minimum cover of 24 inches; however, buried piping under railroads, roads, streets, or highways may have less cover if pipes or conduits are protected against possible external damage due to the superimposed car or truck travel.

(i) When pipelines must be laid where they will be subjected to hazards, such as washouts, floods, unstable soils, land slides, dredging of water bottoms, etc., they shall be protected by increasing pipe wall thickness, constructing intermediate supports or by anchors, erosion prevention, covering pipes with concrete, or other reasonable protection.

(ii) Pipelines filled with water shall be buried below the frost line.

(c) For collateral reading on design of underground piping see ANSI B31.1, Section 8.

(d) Manholes shall conform to NAVFAC Guide Specification TS-15705.

(e) Tunnels for underground routes shall be large enough for human traverse by walking, with piping stacked vertically on one side and enlarged zones for crossovers and takeoffs. Enough room shall be available to operate wrenches and reach all flange bolts.

(i) A drainage trench shall run along one wall to a point of disposal to a storm sewer or a sump pit, with an automatic drainage pump driven by an electric motor or steam jet.

(ii) Electric conduits carrying high voltage should be excluded.

(iii) Tunnels shall be well lighted and ventilated. Moisture resistant electric fixtures should be used.

(iv) Tunnels may be built of reinforced concrete, brick, or other suitable structural materials, and should be membrane waterproofed.

## Section 5. MISCELLANEOUS CRITERIA

1. TYPHOON CONSIDERATIONS. Exterior distribution systems shall be anchored or guyed (as required) to withstand the wind velocity specified for design of structures, (Structural Engineering, NAVFAC DM-2 series). Designs for all exterior piping systems shall be given special attention to ensure minimum damage due to typhoon phenomena.

## REFERENCES

(Publications containing criteria cited in this manual)

Keenan and Keyes. Thermodynamic Properties of Steam, J. Wiley & Sons, N.Y.

Crocker and King. Piping Handbook, McGraw-Hill.

ASHRAE, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, NY 10017. ASHRAE Handbook and Products Directory.

ANSI, Standards, American National Standards Institute, New York, NY 10018: ANSIB31.1 Power Piping, ANSI B31.2 Fuel Gas Piping, and ANSI B31.8 Gas Transmission and Distribution Piping Systems.

HI publications, Hydraulic Institute, New York, NY 10017. Pipe Friction Manual.

NAVFAC Specifications and Standards, available at U. S. Naval Publications and Forms Center, Philadelphia, PA 19120. Telephone number: AUTOVON-442-3321; commercial--(215) 697-3321.

NAVFAC Guide Specifications:

| | |
|---|---|
| TS-02711 | Outside Gas System |
| TS-15411 | Compressed Air System (Non-breathing Air Type) |
| TS-15705 | Underground Heat Distribution System (Prefabricated or Pre-Engineered) |
| TS-15707 | Reinforced Thermosetting Resin Plastic (RTRP) Pipe Condensate System |
| TS-15 P28 | Heat Distribution Systems Outside of Building (Cancelled, Copies available at NAVFAC HQ) |
| 53Y | (Cancelled, Copies available at NAVFAC HQ) |

NAVFACENGCOM Design Manuals and P-Publications.

Government agencies may obtain Design Manuals and P-Publications from the U.S. Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120. TWX 710-670-1685, AUTOVON: 442-3321. The stock number is necessary for ordering these documents and should be requested from the NAVFACENGCOM Division in your area.

Non-Government organizations may obtain Design Manuals and P-Publications from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

| | |
|---|---|
| DM-2 series | Structural Engineering |
| DM-3 series | Mechanical Engineering |
| DM-7 series | Soil Mechanics, Foundations and Earth Structures |
| DM-24 series | Land Operational Facilities |
| P-272 (Part 1) | Definitive Designs for Naval Shore Facilities |

## APPENDIX A

## METRIC CONVERSION FACTORS

0.5 inch = 13 mm

2 inches = 51 mm

3 inches = 76 mm

4 inches = 102 mm

6 inches = 152 mm

8 inches = 203 mm

10 inches = 254 mm

12 inches = 305 mm

24 inches = 610 mm

1 foot square = 0.3 m square

2 feet = 610 mm

3 feet = 914 mm

5 feet = 1524 mm

14 feet = 4267 mm

16 feet = 4877 mm

22 feet = 6706 mm

50 feet = 15,240 mm

100 feet = 30,480 mm

200 feet = 61,000 mm

300 feet = 91,400 mm

500 feet = 152,400 mm

2 fps = 610 mm/sec

5 fps = 1524 mm/sec

15 psig = 103 kPa (kilopascals)

30 psig = 207 kPa

50 psig = 345 kPa

100 psig = 689 kPa

125 psig = 861 kPa

150 psig = 1034 kPa

3000 pph = 1361 kg/hr

$450^{\circ}F = 232^{\circ}C$